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EarthCARE BBR Fluxes evaluation using test scenes

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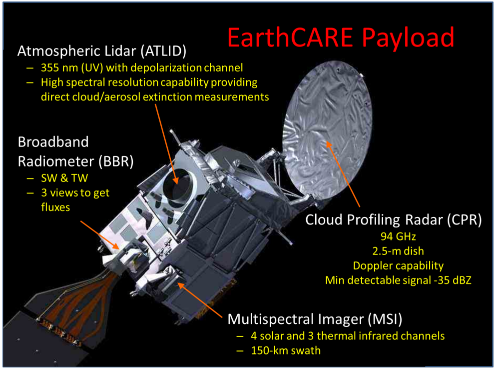
2022 Earth Radiation Budget Workshop


Credit: ESA P. Carril, 2013

The EarthCARE mission

- EarthCARE is the sixth Earth Explorer Mission of the ESA Living Planet Program. (Scheduled for launch in 2023/2024)
- Objectives: Improve understanding of cloud-aerosol-radiation interactions so as to include them correctly and reliably in climate and NWP models



- EarthCARE radiative mission requirement: constrain retrievals of cloud and aerosol properties defined by the active sensors such that TOA radiative fluxes are accurate to within $10 Wm^{-2}$
- Orbit: Sun-synchronous, DN 14:00 Height: 393 km mean spherical altitude (394.4km for cal/val orbit)

EarthCARE Production Model

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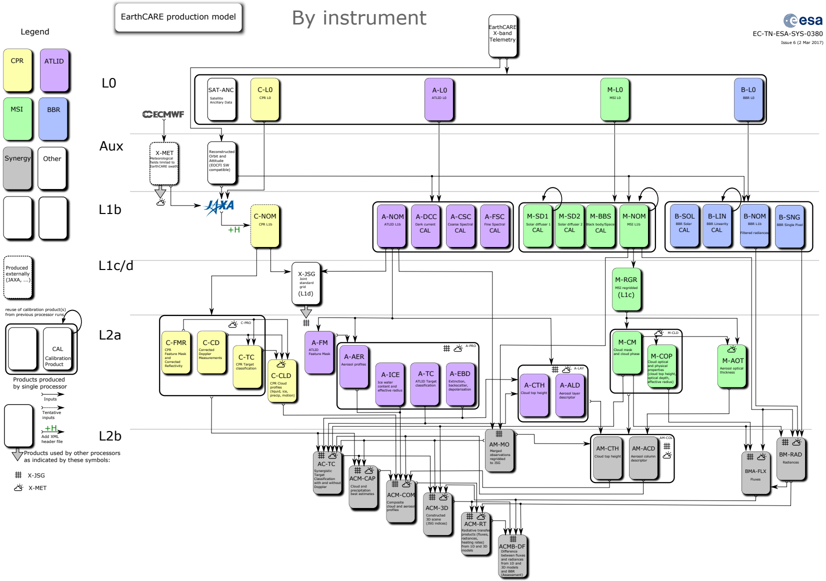

EarthCARE Production Model

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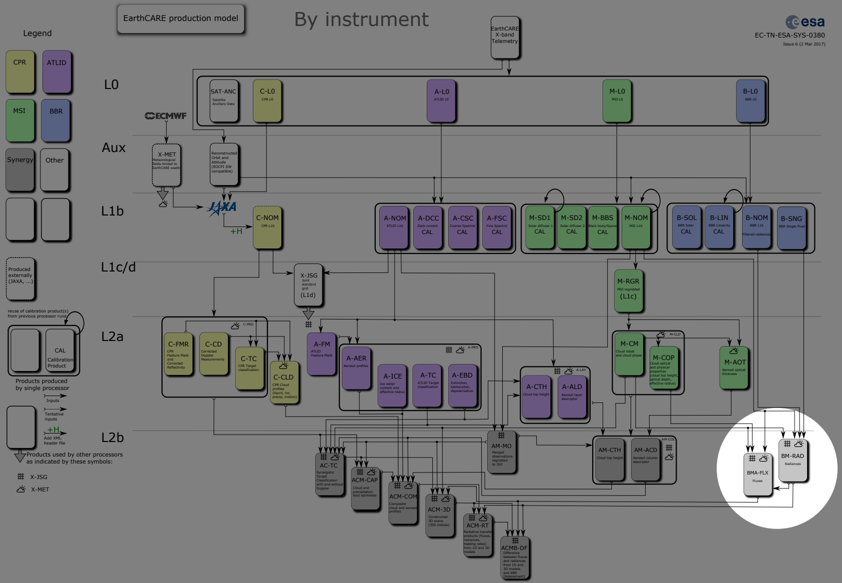

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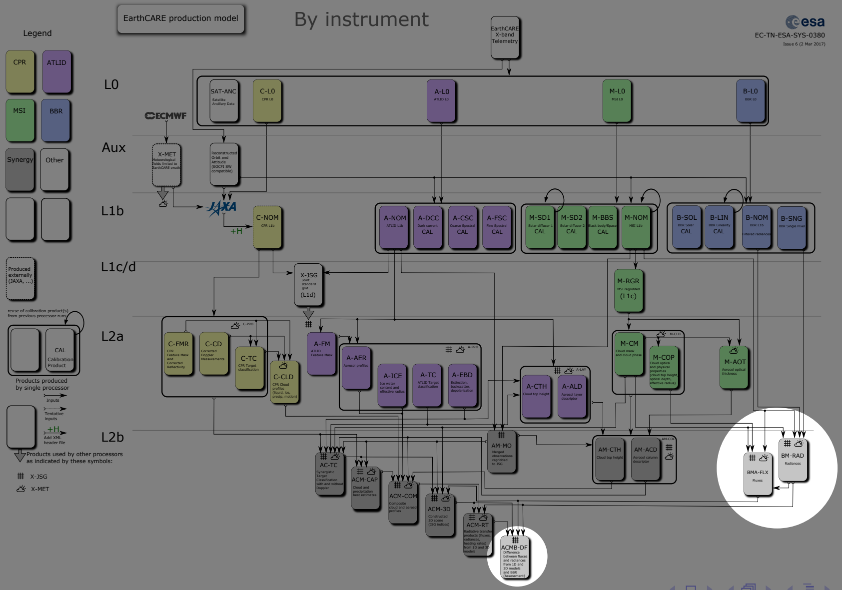
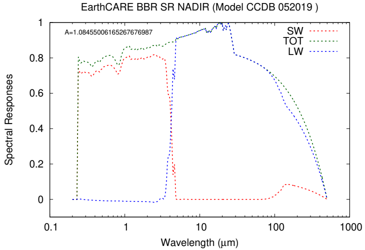


BBR Configuration

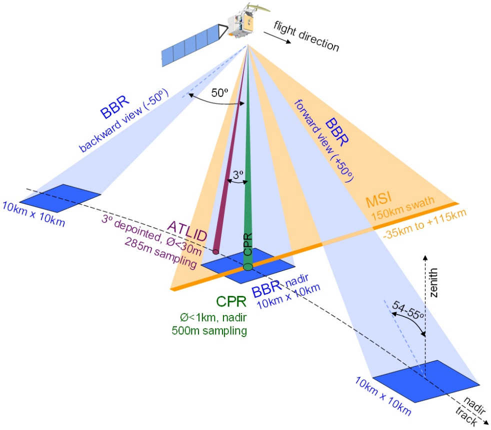
- Along track sampling: 3 telescopes (nadir 0°, fore +55°, aft -55°)
- Two spectral channels:

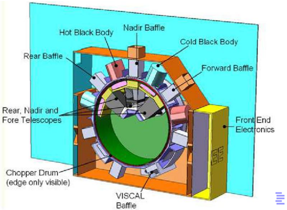
  SW (0.2 - 4 μm)
  TOT (0.2 - 500 μm)



- Radiometric accuracy:

  SW $2.5\ \mathrm{Wm^{-2}sr^{-1}}$
  LW $1.5\ \mathrm{Wm^{-2}sr^{-1}}$





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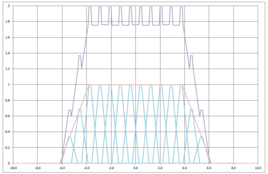
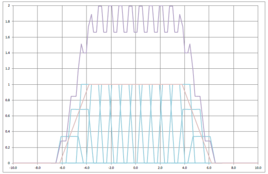
Integration areas

- On BBR grid:
  - $10x10km^2$: Standard resolution
  - $5x10km^2$: Small resolution
  - Full swath $x10km^2$: Full resolution (no combined flux)
- On Joint Standard Grid (JSG):
  - 5 x 21 JSG pixels: assessment domain (configurable)

	Full speed
Nadir	
Oblique	

10km along track integration

Notes : - all regions sampled @ 1km - dimensions are configurable

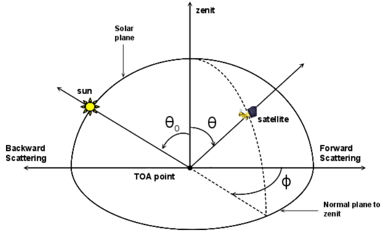
BBR Flux estimation

- BBR measure radiances $L(\theta,\phi)$ $[Wm^{-2}sr^{-1}]$ at the TOA but flux is

$$F = \int_{\theta=0}^{\frac{\pi}{2}} \int_{\phi=0}^{2\pi} L(\theta,\phi) cos(\theta) sin(\theta) d\theta d\phi$$

- Need of Angular Dependency Models (R)

$$F = \frac{\pi L(\theta,\phi)}{R(\theta,\phi)}$$



- In the LW:

$$R(\theta) = a_0 + a_1 \cdot z_1 + a_2 \cdot z_2 + a_3 \cdot z_1^2 + a_4 \cdot z_1 \cdot z_2 + a_5 \cdot z_2^2$$
$$z_1 = BT_{10,8\mu m}, z_2 = BT_{12\mu m} - BT_{10,8\mu m}$$

- Need a geophysical database to obtain a_i: Use of SITS Database
- BBR 3 views flux is estimated as:

$$F = \frac{1-\alpha}{2}(F_{fore} + F_{aft}) + \alpha F_{nadir}$$

- In the SW:

  ADMs are feed-forward back-propagation artificial neural networks
  Need a geophysical database for network training:
  - CERES flux/radiance (SSF Ed. 4)
  - ERA-20C
  - MODIS albedo climatology
  - AERONET climatology

- BBR 3 views flux is estimated as:

$$\overline{F}_{SW} = \frac{1}{\varepsilon_N}\left(\frac{1}{\varepsilon_{Faft}\varepsilon_{Raft}}F_{aft} + \frac{1}{\varepsilon_{Fnad}\varepsilon_{Rnad}}F_{nad} + \frac{1}{\varepsilon_{Ffore}\varepsilon_{Rfore}}F_{fore}\right)$$

  If fractional error is below a threshold, flux estimates are averaged by weighting the fluxes by their estimated error and the radiometric performance of every view

BBR Reference Level

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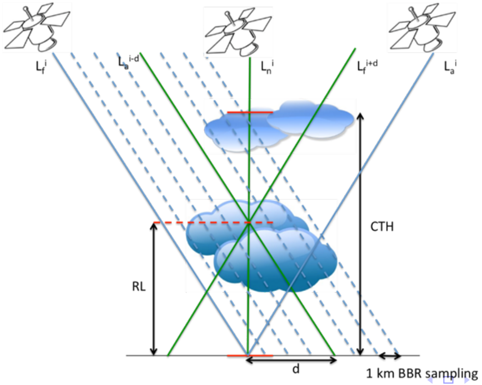
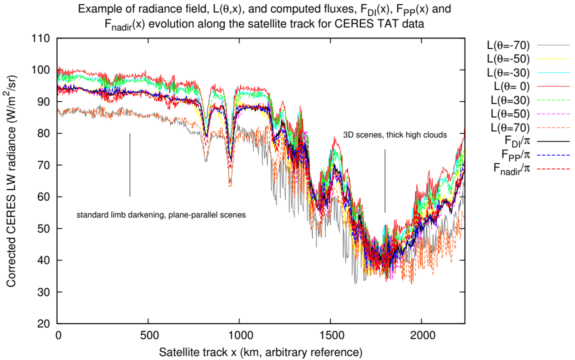
- Important to define Flux reference level for the collocation of the views to avoid parallax
- LW: The reference level will be placed at the altitude of the highest cloud in the footprint (using statistics on the MSI cloud top height product in nadir)
- SW: Views are co-registered at a RL defined as the vertical level in the atmospheric nadir domain that minimizes the flux differences between the nadir, aft and fore flux retrievals



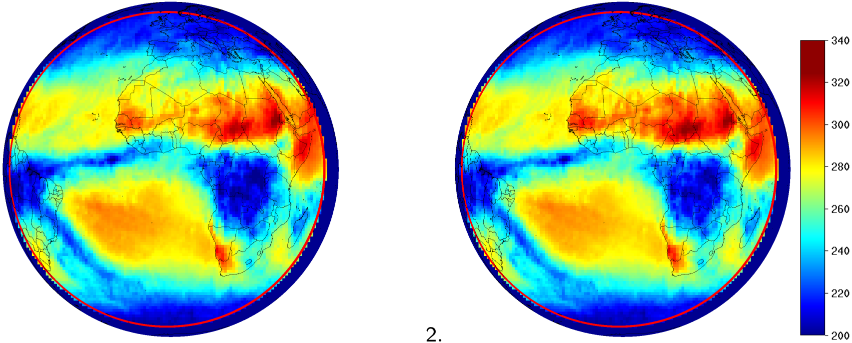
Best weighting of the nadir view.

- Study based on CERES TAT data, allowing to estimate the true flux (Direct Integration)
- Best weigthing using real data: $\alpha \sim 1/3$
- 3D effects are important and the three views should be considered



LW: Regional Analysis Validation

Comparisons of GERB/BBR-like data with collocated CERES - March 2004



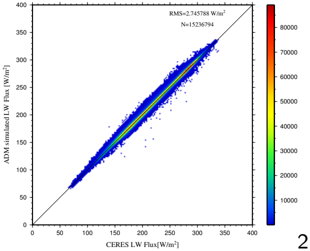
1. 2.

(1) Mean CERES Flux March 2004. (2) Mean GERB/BBR Flux March 2004

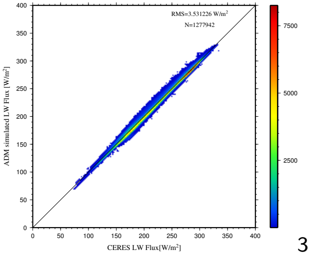
$F_{BBR-like}$ vs $F_{CERES}(Wm^{-2})$

	GERB 4 LibRadtran + SBDART	GERB 4 Ed-1 SBDART	BBR 2 BT Improved DB bins 20 W m^{-2}
Nadir	6.9	7.9	6.1
Off-nadir	7.6	7.6	7.7
θ<60	7.6	7.8	7.2

LW: Theoretical ADM's applied to CERES SSF Ed-3A data March 2004



1.



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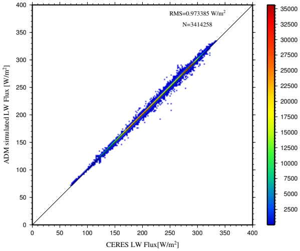
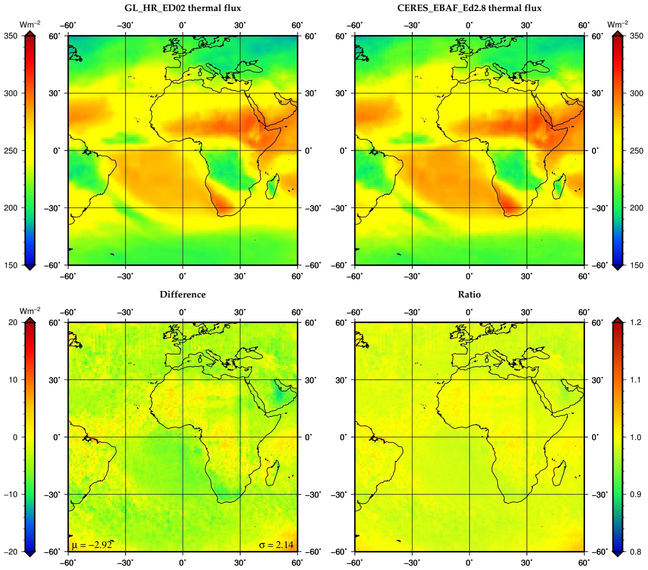


3.

(1) All viewing zenith angles. $RMS = 2{,}75 Wm^{-2}$
(2) Nadir ($\theta < 5$). $RMS = 3{,}56 Wm^{-2}$
(3) Off-nadir ($50 < \theta < 55$).$RMS = 0{,}98 Wm^{-2}$

LW: Theoretical ADM's applied to CERES EBAF data Dec 2005



SW: Sample of validation over ocean using CERES data

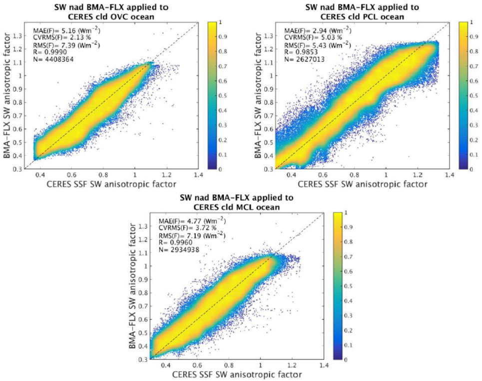


Figure 20 Density scatter plots of the SW anisotropic factors estimated with the nadir BMA-FLX SW model and the CERES-derived fluxes for (bottom) cloudy MCL ocean, (left up) cloudy OVC ocean and (right up) cloudy PCL ocean scene classes.

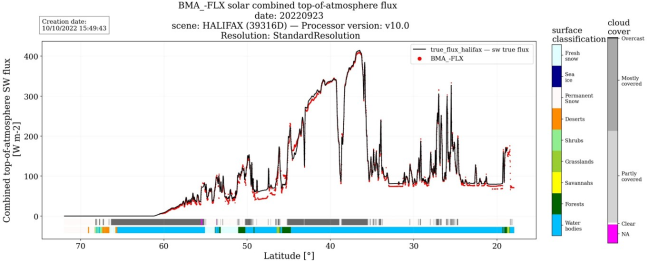
Sky conditions	ADM	RMS (W m^{-2})	CVRMS (%)	P_{33}(MAE) (W m^{-2})	P_{66}(MAE) (W m^{-2})	P_{99}(MAE) (W m^{-2})	Samples
clear-sky	nadir	4.21	2.14	0.87	2.42	14.28	3618993
	forward	4.12	1.86	0.81	2.28	15.35	856146
	backward	4.22	2.23	0.88	2.37	15.38	808108
cloudy-sky	nadir	6.05	2.35	1.48	3.99	20.77	17601681
	forward	5.30	2.09	1.50	3.73	18.31	7402302
	backward	4.31	1.89	1.23	2.98	15.42	7369598
all-sky	nadir	5.78	2.34	1.34	3.71	19.97	21220674
	forward	5.19	2.08	1.40	3.60	18.03	8258448
	backward	4.30	1.92	1.19	2.93	15.42	8177706

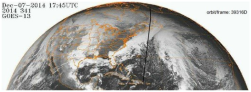
RMI gmv

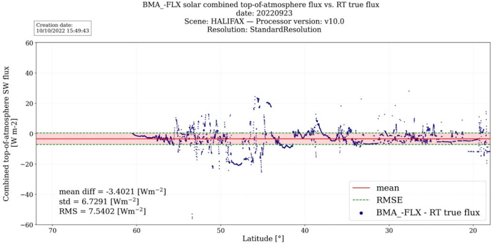
End-to-end validation using test scenes

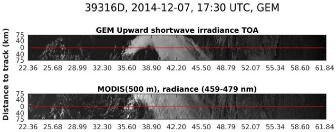
- Three test scenes have been created by EC and KNMI by applying instrument simulators to the model data from the Global Environmental Multi-scale (GEM) NWP model.
- The resulting estimates go into radiative transfer models that produce top of atmosphere solar and thermal radiative quantities.
- The test frames are 6200 by 200 km with horizontal resolution of 250m and 57 vertical layers.
  - Halifax: Greenland to The Caribbean crossing a cold front
  - Baja: Nunavut to Baja California over the Rocky Mountains
  - Hawaii: central equatorial Pacific Ocean including a mesoscale convective system

Halifax scene: SW



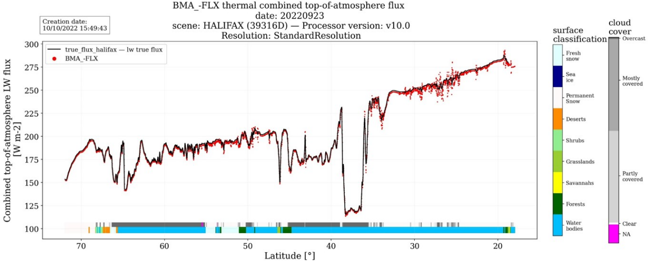


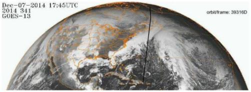


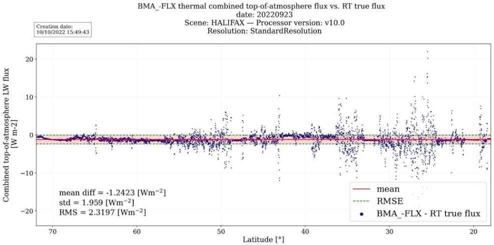


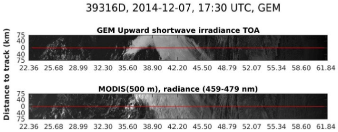
This case includes Sun just below the horizon over Greenland, cold air over Labrador, a cold-front near Halifax, dense overcast south of Halifax, and scattered shallow convection south of Bermuda

Halifax scene: LW









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Baja scene: SW

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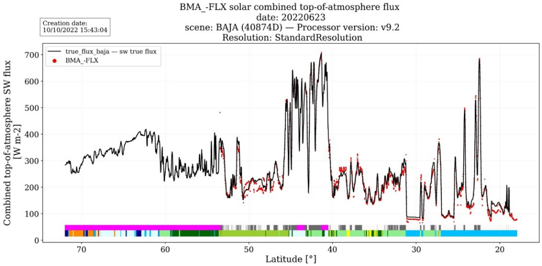
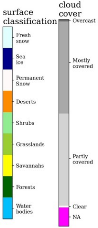
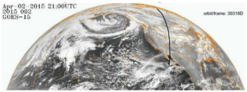
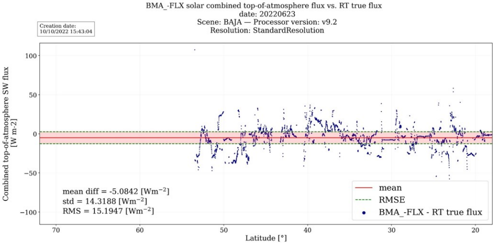
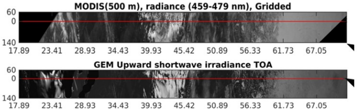








	Temperature	Windchill	Dew Point	Humidity	Pressure	Vis (km)	Wind Dir	Wind Speed	Conditions
Gjoa Haven	-26.0 °C	-37.6 °C	-29.0 °C	77%	1024.0 hPa	24.1	NNW	18.5 km/h	Ice Crystals
Baker Lake	-27.0 °C	-43.6 °C	-31.0 °C	70%	1017.9 hPa	4.8	N	40.7 km/h	SnowBlowing + Snow
Ennadai	-28.2 °C	-46.5 °C	-32.2 °C	70%	1025.2 hPa		NNW	50.0 km/h	Blowing
Key Lake	-11.0 °C	-17.4 °C	-22.0 °C	41%	1024.7 hPa	14.5	N	13.0 km/h	Clear
Saskatoon	0.0 °C	-3.6 °C	-10.0 °C	48%	1023.6 hPa	24.1	NE	11.1 km/h	Mostly Cloudy
Billings	7.2 °C	3.3 °C	-12.8 °C	23%	1021.4 hPa	16.1	NW	25.9 km/h	Scattered Clouds
Big Piney	1.7 °C	-1.9 °C	-16.1 °C	26%	1016.6 hPa	16.1	NW	13.0 km/h	Overcast
Provo	8.0 °C	5.0 °C	-6.0 °C	37%	1019.2 hPa	24.1	WNW	18.5 km/h	Mostly Cloudy
Page	18.9 °C		-15.6 °C	9%	1008.3 hPa	16.1	W	35.2 km/h	Clear
Phoenix	28.9 °C		0.6 °C	16%	1010.0 hPa	16.1	WNW	22.2 km/h	Mostly Cloudy
Hermosillo	34.0 °C		2.0 °C	13%	1011.7 hPa	16.1	SSW	29.6 km/h	Scattered Clouds
La Paz	31.0 °C		9.0 °C	25%	1012.9 hPa	16.1	W	11.1 km/h	Mostly Cloudy



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Baja scene: LW

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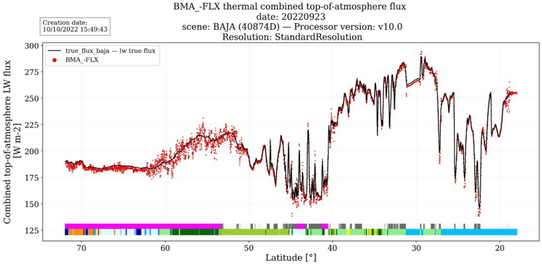

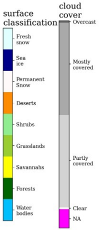

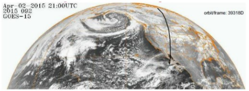

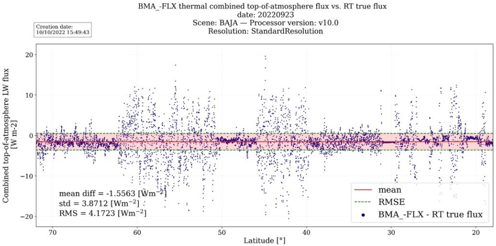

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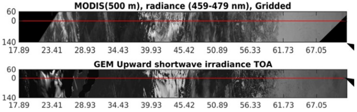

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Hawaii scene: SW

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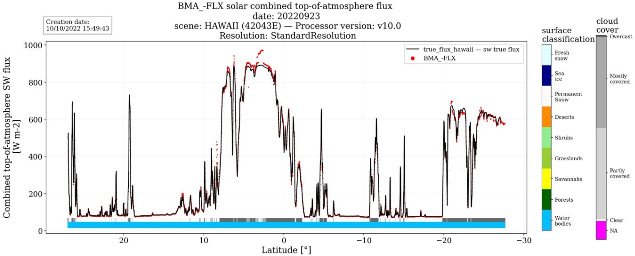
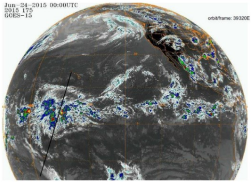
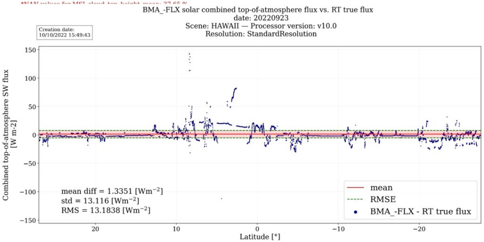
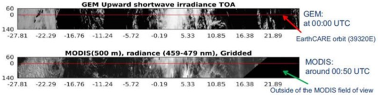


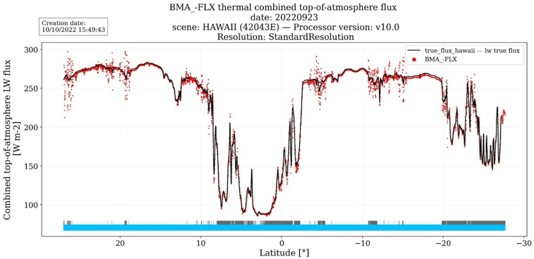


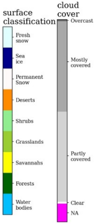


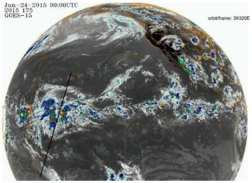


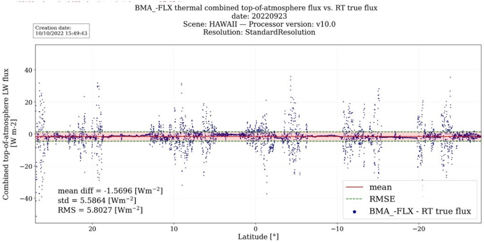
Central equatorial Pacific Ocean including a mesoscale convective system

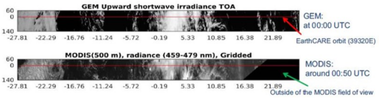
Hawaii scene: LW











Central equatorial Pacific Ocean including a mesoscale convective system

Summary

- A radiance to flux conversion algorithm has been developed for the BBR
- Estimated performance:
  - LW: Nadir $\sim 3{,}5 Wm^{-2}$, off-nadir $\sim 1 Wm^{-2}$ for plane-parallel scenes $\sim 7 Wm^{-2}$ for 3D scenes
  - SW: $\sim 15 Wm^{-2}$ for the combined flux
- L2 processors have been chained and been verified using test scenes.
- Algorithms are documented in the ATBD
- LW ADMs to be used in GERB Ed-2 LW Flux

- For more information see:
  - BAMS Article: The EarthCARE Satellite. August 2015
  - AMT Special Issue on EarthCARE L2 algorithms and data products to come in 2023.
  - JAXA EarthCARE Pre-Launch Science and Validation Workshop 2023 (9-13 October 2023, ESA-ESRIN, Italy)